The Use of Storm Water Infiltration and Storage Techniques – Bonaero Park, South Africa

Utilization de techniques d'infiltration et de retention des eaux pluviales – Bonaero Park South Africa

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RESUME

L'utilisation de multiple aménagements de retenue et d'une tranchée d'infiltration dans une zone résidentielle de Kempton Park a permis de lancer une étude sur les effets que de tels aménagements peuvent avoir en réduisant les pics d'écoulement produits par des orages d'intensité moyenne ou forte ainsi que de contrôler les écoulements des eaux pluviales au travers du système d' évacuation existant, et par là d'optimiser et d' accroître les capacités et l'efficacité du système existant. Trois aménagements de ce type furent construits. Le détail qui est fourni permet la mise en œuvre de chacun de ces aménagements complémentaires et ainsi d'améliorer la performance du système existant. L'objectif principal de cet exercice était de maintenir les écoulements maximums dans la zone résidentielle à un niveau de valeur égal ou inférieur au niveau antérieur au développement.

ABSTRACT

The use of multiple retention facilities and an infiltration trench within a residential area of Kempton Park introduces a study into the effects such structures will have on decreasing the high run-off peaks generated by average to high storm events and to control the flows through the existing storm water system, thereby optimizing and extending their current capacities and efficiency. Three such structures were constructed. Detail is provided to the benefits of implementing each of these complementary devices and the performance of the system. The main goal of this exercise was to keep the maximum run-off flows in the residential area at values equal or below the pre-development values.

KEYWORDS

BMP, Infiltration trench, Storm water management

1 INTRODUCTION

During storm events of moderate to high intensities experienced in the summer rainfall month of October 2001, flooding of residential properties in Bonaero Park adjacent to the Johannesburg International Airport, South Africa, occurred which led to the Bonaero Park Community Group taking legal action against the Local service provider for a lack of service delivery and damages to property. This led to the following study and subsequent construction of a detention dam, attenuation channel and an infiltration trench designed with the primary aim of attenuating flood peaks in stead of its normal infiltrative purposes.

Development and the deforestation of the upstream areas have lead to the increased flood volumes experienced during the rainfall season. It was the aim of the study to determine the influence of commercial development, upstream from Bonaero Park, will have on the current, already insufficient, network.

1.1 Aspects of the study area

The total contributing area is 850 hectares in size with current weighted percentage imperviousness of 21.3% which is indicative of residential and small commercial developments. The area is situated on a flat watershed with the Johannesburg International Airport covering most. Development is predominantly light commercial with gravel parking areas, paved surfaces and buildings all draining towards the residential area of Bonaero Park. It is the aim of the Airports Company South Africa (ACSA) to develop the area for commercial purposes which will result in an increased run-off. A main arterial route (K90) is also planned which will act as a cut-off between the two development types. The construction of the K90 will result in the run-off being concentrated to culverts along the route.

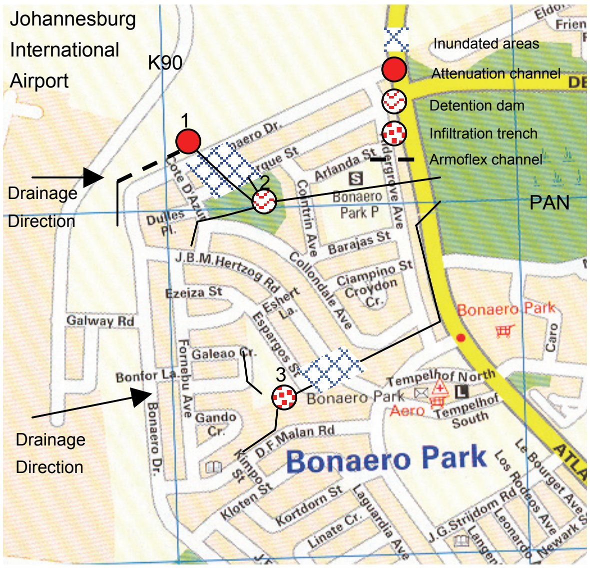

Figure 1: Remedial measures layout

1.1.1 Existing storm water network

The existing storm water network comprise of small diameter conduits draining underneath residential stands as well as an armoflex lined channels to cut-off run-off from the airport property (Source of most of the stormwater run-off). The armoflex channel discharges into a pipe system underneath residential stands to a park stand where it daylights into an unlined open drain which in turn conveys the run-off to a 1050mm Ø pipe. From here it is conveyed to a pan some 800m downstream. The 1050mm Ø drains underneath houses, a school and townhouses.

2 DESIGN METHODOLOGY

Three deterministic models were compiled to analyse the system and to investigate the preliminary solutions. Once a basic cost benefit analysis was completed, the proposed solutions were analysed in more detail.

Mean Annual Precipitation	651 mm
Routing in conduits	Kinematic
Overland routing	Time-area
Infiltration model	Modified Horton
Storm distribution type with time to peak ration of 0.4	Triangular
I-D-F	HRU1/78
Design storms (min)	60 - 120
Recurrence interval (years)	20

Table 1: Typical model characteristics

Model 1 : Pre-development model

This model was compiled to determine the current status of the system. An initial synthetic storm was simulated to replicate the events of October 2001. The synthetic hydrograph resulting from the simulation was found to be very similar to that from the flood producing storm event. Once this has been determined, the approximate recurrence interval was determined. It was found to be less than the design storm with a 5% probability as required. The results of model 1 clearly indicated that the existing system was undersized and in-efficient.

Model 2 : Post development model

The future land development plan was used to determine the post development conditions of the area. The appropriate variable was changed from model 1 to reflect these changes. The variables for the areas where a large scale of eradicating of foreign vegetation took place were also changed. It was found that the development would result in a 148% increase in the un-off volume due the planned commercial developments.

At this stage, various possible alternative solutions were investigated. Among them the following :

ALTERNATIVE	CONSTRAINTS
Open retention facility within development area	Cost benefit yields best results at 1:10 year standard which is to low (1:20 required). No open facilities allowed within development area due to the possibility of the creation of a wetland area. This may attract animals and birds which will interfere with aircraft flight paths. Permission for construction within ACSA property was not granted.
Dual pipe system	To costly. Area underlain with rock and excavations in excess of 7m required. Slope of 0.5% to outfall will not be maintained.
Infiltration devices	Uncertainty of dolomites in underlying layers. No core drilling was performed for geotechnical investigation.
Alternative systems	To costly. Deep excavations over long distances to acquire adequate slopes.
Upgrading of existing storm water systems	To costly. The systems drain underneath residential properties which include communal flats, townhouses and houses. This would require systems to be jacked over long distances.
Expropriate	To costly and no cooperation from community could be expected.

Table 2: Alternative solutions and project constraints

Model 3 : Remedial model

Model 3 was compiled to analyse the proposed remedial measures.

2.1 Alternative selected

Areas for possible retention/attenuation were identified and model 3 changed accordingly to determine the attenuation needs. The proposed remedial measures were:

2.1.1 Attenuation channel

The final selected alternative comprised of the construction of an attenuation channel as a replacement to the armoflex channel. The attenuation channel has two outlets. A 900mm Ø at the invert level and a 450mm Ø pipe aligned 300mm below the top edge of the channel. Both pipe systems where already in place and drains underneath the residential stands to a public open space. The public open space will be utilised as a secondary retention pond and the existing unlined channels, flattened out and lined with indigenous grass. The aim was to retain the run-off originating from the Airport property to such a degree that the run-off from the urban drainage network has adequate time to exit the system.

Performance – Attenuation channel		
	Inflow	Outflow
Maximum total Flow (m³/s) – 1:20Y	7.582	3.628
Time to maximum (min)	62	39
Maximum Storage yield (m³)		14680
Attenuation (%)		53%
Lag Time (min)		23
Dimensions (m) – trapezoidal: length = 90; depth = 2; top = 3.5, bottom = 2		
Outlet: 1/900mm Ø at invert of channel & 1/450mm Ø 300mm below edge. No spillway		

Table 3: Attenuation/retention analysis

Figure 2: Armoflex channel

Figure 3: During construction

49% attenuation was required to retain the flood peak to acceptable levels.

2.1.2 Detention dam (secondary retention facility)

A detention dam was constructed to retain the excess run-off from the urban network as well as the discharge from the attenuation channel. The storage basin is lower than the properties and road surfaces to act as an additional precautionary measure.

Performance - Retention Pond – Stand 768		
	Inflow	Outflow
Maximum total Flow (m³/s) 1: 20Y	5.273	1.183
Time to maximum (min)	77	33

Maximum Storage yield (m³)	17072
Attenuation (%)	77.5
Lag Time (min)	44
Dimensions (m) – 25 x 25 x 1	
Outlet: 1/1050mm Ø. No spillway	

Table 4: Retention analysis

2.1.3 Infiltration trench

An infiltration trench, with dimensions 27m x 3.5m x 2m, was constructed with the aim of sufficiently retaining/control the run-off peak from the existing stormwater network in an attempt to prevent flooding at downstream properties. This was achieved by altering the flow from a 450 mm Ø pipe to a sump chamber (3.5m x 1m x 2m) at the upper end of the trench. The trench has a volume of 189 m³, filled with no-fines coarse gravel (porosity of 40%). The gravel is enveloped by a geofabric filter to retain the sump water and preventing fine material to infiltrate into the system. Head is provided in the sump by the entering waters, forcing the stormwater through the gravel bed. Very high infiltration rates are achieved but due to the length of the bed, sufficient lag is obtained thereby allowing downstream systems to drain before receiving the run-off from the trench. The bed is constructed in a small retention (0.5m spill height) dam for the control of additional overland run-off and as a contingency measure, should the system clog at either the junction box or the sump chambers. 3/50mm UPVC sleeve pipes connect the sump chambers for cleaning of the chambers and removing sediment deposits. The

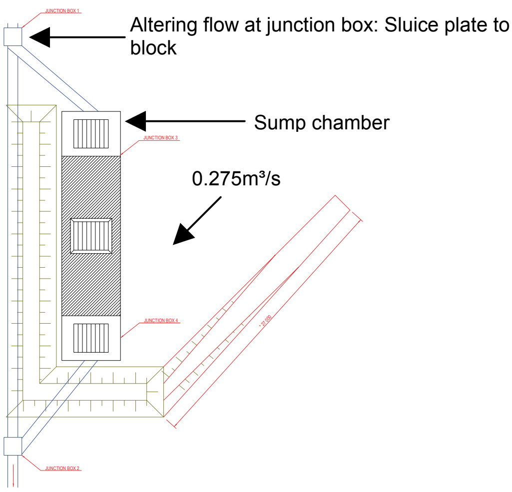

Figure 4: Infiltration trench layout

Figure 4 : Infiltration trench – after construction

Figure 5 : Infiltration trench – after construction

3 PERFORMANCE

Storm water planning for the Bonaero Park site started in late 2002, with construction commencing in the winter months of 2003. The storm water management controls have been in place for three years and from figure 2 below, it can be seen that in the three years since the construction of the structures, storm events have occurred with rainfall intensities in excess of that experienced in October 2001. Since the construction of the structures no flood related complaints have been received from the community. The K90 main route and access routes have also been constructed.

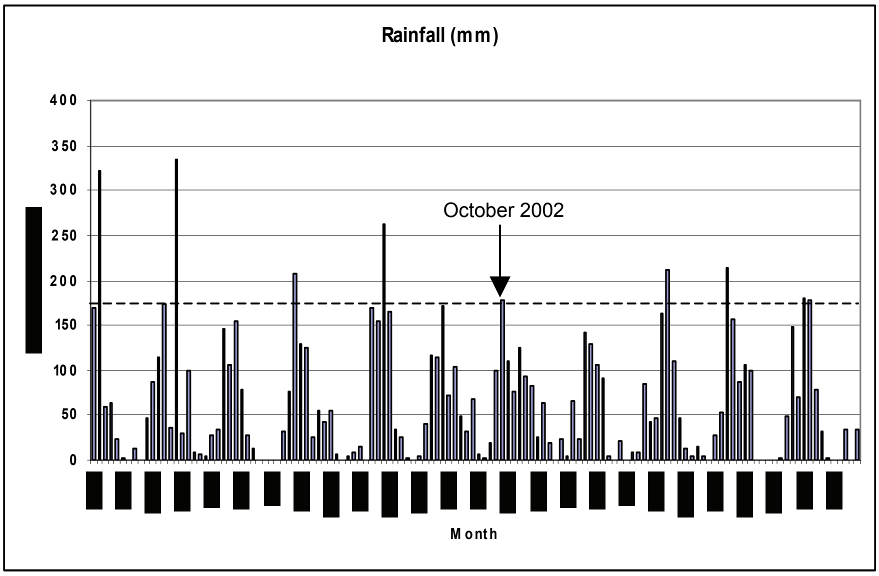

Figure 6: Rainfall data (1996 – 2006)

4 ACKNOWLEDGEMENTS

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